**DESIGN OF ATOMIZERS AND BURNERS FOR
COAL-WATER SLURRY COMBUSTION**

QUARTERLY ACTIVITY REPORT

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Abstract

A new, miniature Triple-Concentric atomizer was designed, constructed, and underwent preliminary testing. Atomization tests of a set of aqueous polymer solutions were conducted on the existing TCA.

Table of Contents

Disclaimer	2
Abstract	3
Executive Summary	5
Introduction	5
Results and Discussion	6
Conclusion	7
Projected Activity for Next Period	7

List of Figures

Figure 1: Schematic Diagram of Miniature Triple-Concentric Atomizer	8
Figure 2a: Spray Cone Composite Image (Mini. TCA, Center Tube Recess = 0)	8
Figure 2b: Spray Cone Composite Image (Mini. TCA, Center Tube Recess = 0.5 D)	9
Figure 2c: Spray Cone Composite Image (Mini. TCA, Center Tube Recess = 1 D)	9
Figure 2d: Spray Cone Composite Image (Mini. TCA, Center Tube Recess = 1.5 D)	10
Figure 2e: Spray Cone Composite Image (Mini. TCA, Center Tube Recess = 2 D)	10
Figure 2f: Spray Cone Composite Image (Mini. TCA, Center Tube Recess = 2.5 D)	11
Figure 3: Spray Cone Angle vs. Center Air Tube Recess (Mini. TCA)	11
Figure 4: Liquid Reservoir Vacuum vs. Air Flow Rate at Various Recess Distances (Mini. TCA)	12
Figure 5: SMD Values of Atomized Polymer Solutions	12
Figure 6: SMD Variation with Center Air Flow Rate; Polymer Solutions	13
Figure 7: Variation of SMD with Liquid Flow Rate; Polymer Solutions	13

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Progress Report for Period 4/1/98 - 6/30/98

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Executive Summary

A new, miniature variation on the Triple-Concentric atomizer (TCA) was designed and constructed. This prototype will be used to test the applicability of the TCA concept to very fine sprays such as medical nebulizers. Preliminary tests of its performance with plain water were conducted. Atomization tests of an aqueous polymer solution were conducted using the existing TCA. These tests show that there is little change in the Sauter Mean diameter as polymer concentration or molecular weight are increased until the polymer molecules become highly intertwined.

Introduction

This report documents the activities and results from the period 1 April 1998 to 30 June 1998 and the planned activities for the next period, 1 July 1998 to 30 September 1998. Two primary activities were undertaken in this period: investigation of the variation in performance of a miniature triple-concentric atomizer (hereafter, *TCA*) with variation in air flow rate and center air tube location; and droplet size measurements of water and aqueous polymer solutions generated by the existing triple-concentric atomizer.

Miniature TCA

A miniature TCA was constructed with a moveable center air tube was constructed (see Fig. 1). Although this miniature atomizer is constructed on the same principle as the TCA, it was operated solely as an “inverse” twin-fluid annular atomizer. Standard twin-fluid atomizers surround a cylindrical liquid jet with a high-speed annular air jet. The inverse twin-fluid atomizer surrounds a high-speed cylindrical air jet with an annular liquid jet. The inverse twin-fluid atomizer may have many of the advantages of the triple-concentric atomizer with marginally reduced complexity.

Aqueous Polymer Solutions

Solutions of poly-(ethylene oxide) (hereafter, PEO) in water were used to investigate the atomization of polymeric liquids. Several different concentrations were used. For each

PEO solution, a mixture of glycerol and water was used as the solvent to keep the shear viscosity at low shear rate constant. The baseline case was a 50% by weight solution of glycerol and water.

Results and Discussion

Miniature Triple-Concentric Atomizer

The breakup region of the miniature TCA was examined by visualization using a Greenfield Speedview 700 system. The Greenfield uses a CCD camera to obtain strobe-backlit images of a spray. The video acquisition system on the attached personal computer can measure the diameter of the droplets for sizing or save the images for visualization. For this experiment, many images were obtained and digitally overlaid using Adobe PhotoShop software.

The composite images are shown in Figures 2a through 2f. In each figure, the darker areas represent the presence of liquid at that location in a greater number of individual images. The recess distance of the center air tube is measured in terms of the inside diameter of the liquid tube. The recess distance was varied from zero to 2.5 diameters in increments of 0.5 diameters. As the recess distance increases, the cone angle of the spray decreases dramatically; this effect is plotted in Figure 3.

The degree of atomization appears to decrease with increasing recess distance as well. However, the liquid flow in this TCA is induced by the airflow. At a given air flow rate, the liquid flow rate varies with the recess distance. The pressure in the liquid reservoir was measured and plotted against airflow rate and recess distance (see Figure 4). The liquid flow rate will vary directly with the pressure differential across the liquid tube.

Aqueous Polymer Solutions

Atomization tests of the TCA constructed during the first quarter of 1998 were conducted with a set of aqueous polymer solutions. Droplet size distributions were measured using the Malvern 2600 Laser Diffraction Particle Sizer. Five solutions were tested: one baseline solution of 50% by weight of glycerin in water; 0.3% and 1.1% by weight solutions of PEO with a molecular weight of approximately 100,000; and 0.075% and 0.15% by weight solutions of PEO with a molecular weight of approximately 1,000,000. The glycerin fraction of the glycerin/water mixture used as the solvent was varied to maintain constant shear viscosity in all five samples. The shear viscosity, at very low shear rate, was 5 centipoise for all five samples.

The atomization conditions for each sample were varied through the following ranges:

Liquid Flow:	70, 140, and 210 mL/min
Center Air Flow:	0, 50, 60, and 70 L/min
Outer Air Flow:	0 and 160 L/min

The liquid flow rate was controlled with a syringe pump; air flows were controlled by pressure

regulators and measured with rotameters. All size measurements were made on the spray axis at an axial distance of 15 cm.

Figure 5 shows the variation in the SMD of the various liquids when atomized at identical conditions of liquid flow rate, center air flow rate, and outer air flow rate. The low-molecular weight polymer shows little effect on the atomization performance of the TCA, even at relatively high concentration. The high-molecular weight polymer, on the other hand, displays a strong effect, even at concentrations much lower than that used for the low-molecular weight polymer. Figures 6 and 7 show the variation in the SMD with center air flow rate and liquid flow rate, respectively.

Conclusion

The operation of a miniature “inverted” twin-fluid atomizer was studied. The atomization quality and liquid mass flow rate were seen to vary with the distance the center air tube was recessed into the liquid tube. The triple-concentric atomizer demonstrated the ability to effectively atomize polymer solutions.

The results of the recess experiment on the miniature TCA imply that the center air flow may not be sonic, as previously thought. Further study is warranted to determine the actual conditions. Additionally, minimum back-pressure levels for sonic flow must be obtained. Without an under-expanded sonic jet at the air tube exit, the possibility of unstable, oscillatory mixing between the water and air streams before exiting the atomizer is possible. This could lead to “chugging”, where alternating masses of liquid and air exit the atomizer. In this condition, the contact between the phases is limited and very poor, unsteady atomization results.

Projected Activity for Next Period

During the next quarter, important facets of the operation of the triple-concentric atomizer will be examined:

- A theoretical analysis of the airflow in the center air tube will be conducted to ascertain the conditions necessary to obtain the desired sonic airflow at the exit.
- Detailed Phase Doppler particle size measurements will be made of both water and polymer solution sprays.

The development of correlations describing the breakup of these non-Newtonian polymer solutions (as proposed in the Statement of Work) is dependent on a larger body of data than exists at present.

Figure 4: Liquid Reservoir Vacuum vs. Air Flow Rate at Various Recess Distances (Mini. TCA)

Figure 5: SMD Values of Atomized Polymer Solutions

Figure 6: SMD Variation with Center Air Flow Rate; Polymer Solutions

Figure 7: Variation of SMD with Liquid Flow Rate; Polymer Solutions